U.S. Department of the Interior
U.S. Geological Survey, Water Resources Discipline

Issue No. 125
Winter 2009

In This Issue . . .

USGS
science for a changing world

In Situ Sensors for Dissolved Organic Matter Fluorescence: Bringing the Lab to the Field

By Brian Bergamaschi, Brian Downing, Brian Pellerin, and JohnFranco Saraceno

USGS Optical Hydrology Group, CA Water Science Center

What is FDOM?

On the forefront of emerging sensor technologies are fluorescence-based optical sensors designed specifically to measure dissolved organic matter (DOM) in freshwater and coastal systems. DOM includes a broad range of organic molecules of various sizes and composition that are released by all living and dead plants and animals. Measuring the fraction of DOM that absorbs light at specific wavelengths and subsequently release it at longer wavelengths (e.g. fluorescence) is diagnostic of DOM type and amount. Studies have often used the excitation and emission at 370 and 460 nanometer (nm), respectively, to quantify the fluorescent fraction of colored DOM (referred to as CDOM fluorescence or FDOM). Measurements of FDOM have a long history in oceanography as an indicator of terrestrial humic substances in the coastal ocean, but have only recently been adapted for use as water quality monitors in freshwater systems.

Why measure FDOM?

In-situ FDOM sensors have been used in many different environments to provide a relatively inexpensive high resolution proxy for dissolved organic carbon (DOC) concentration and in some cases, other related biogeochemical variables such as trihalomethanes (THM) precursors and methyl mercury (MeHg) concentrations. Several recent studies from a range of environments (wetlands, forested watersheds,

(Continued on page 2)

In Situ Sensors *(Continued from page 1)*

agricultural watersheds and tidal marshes) have revealed predictive relationships between FDOM fluorescence and laboratory DOC concentration (Downing et al., 2009; Saraceno et al., 2009). A study in tidal wetlands found that FDOM is a strong proxy for methylmercury, a contaminant that is costly and difficult to measure (fig. 1). A related study at the Sleepers River watershed in Vermont has successfully provided continuous, high resolution (30-min sampling frequency) proxy for DOC and MeHg concentration for one full year, including harsh winter conditions under ice.

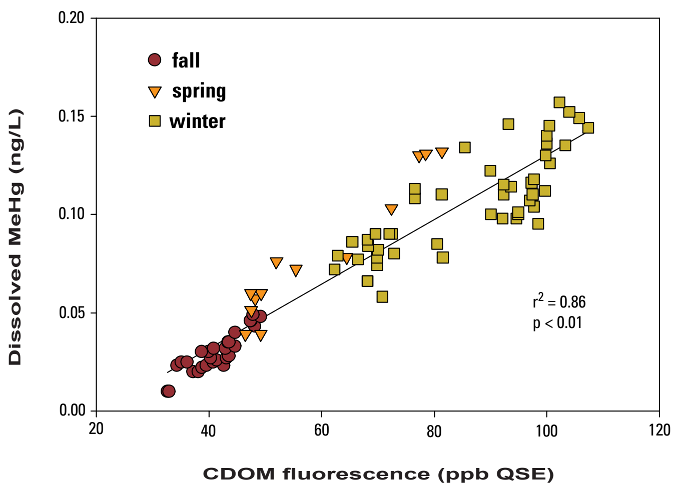

Figure 1. The relationship between in situ FDOM measurements and methylmercury concentrations in surface water of a tidal wetland across three seasons (Bergamaschi et al., in prep.)

How is FDOM measured in the field?

Several companies manufacture in situ FDOM fluorometers (e.g. Wetlabs/CDOM WETStar; Turner/Cyclops 7; Trios/micro Flu CDOM; SeaPoint/SUVF; and HobiLabs/Hydroscat) for a range of applications in freshwater and coastal systems. The principles behind the measurements are the same—inexpensive and low power UV LEDs provide nearly monochromatic excitation and silicon photodiodes are used to measure the emitted light. Instrument design differs in a few important ways—instruments are either flow-through (e.g. the sample is pumped through a quartz tube mounted through the long axis of the instrument) or of the flat faced/optical backscatter type (fig. 2). Both designs can be used in most natural waters, but inorganic and organic particles may interfere with fluorescence measurements in systems with moderate to high turbidity (Saraceno et al., 2009). In highly turbid environments [e.g. greater than 100 Nephelometric Turbidity Units (NTU)], a flow-through sensor deployed with a filter may be the best choice, while the flat faced sensor equipped with a bio-wiper to reduce fouling may be the best choice in systems with low turbidities and biofouling concerns. Other differences between manufacturers include the specific wavelengths measured, flexibility of the platform, and the capability for automating measurements and internal logging.

Figure 2. Two commercially available CDOM fluorometers are shown side by side immersed in a solution of quinine sulfate. Shown on the left, a Turner Designs model Cyclops-7 submersible CDOM fluorometer and right, a WETLabs model ECO submersible CDOM fluorometer.

Most in situ fluorometers have low power requirements, and generate an analog data signal that is easily measured by most U.S. Geological Survey (USGS) data loggers while remaining at a relatively low cost for in situ water quality instruments (e.g. $3-6K). An ideal sensor for a typical application has a wide input voltage range of 7-15 Volts Direct Current (V DC) while consuming less than 500 milliwatts (mW). In situ fluorometers can collect data at intervals ranging from seconds to minutes as it generates a high frequency [>1 Hertz (Hz)] signal available in either 0-5 V analog or a 12-bit digital (RS-232) output. The ideal fluorometer will also maintain a sensitivity of 0.100 ppb quinine sulfate units (QSU) across its entire dynamic range, and is housed in a tough and lightweight sample casing with a simple and rugged design. Wet pluggable bulkheads on all in situ fluorometers is often combined with depth rating to several hundred meters and 0-30 degree Celsius temperature rating, which ensures the units will work in most freshwater environments.

If you have any questions about the FDOM sensors, please contact JohnFranco Saraceno (saraceno@usgs.gov) at (916) 278-3170.

References

Bergamaschi, B.A. , J.A. Fleck, B.D. Downing, E. Boss, B. Pellerin, M.A. Lionberger, N.K. Ganju, D. Schoellhamer, W. Heim, M. Stephenson and R. Fujii. Methylmercury exchange in a tidal estuarine marsh: resolving variability using in situ optical measurements, in prep.

Downing, B.D., E. Boss, B.A. Bergamaschi, J.A. Fleck, M.A. Lionberger, N.K. Ganju, D.H. Schoellhamer, and R. Fujii, 2009. Quantifying fluxes and characterizing compositional changes of dissolved organic matter in aquatic systems in situ using combined acoustic and optical measurements. Limnol. Oceanogr.: Methods 7, 119-131.

Saraceno, J.F., Pellerin, B.A., Downing, B.D. Boss, E., Bachand, P.A.M., and Bergamaschi, B.A., 2009. High Frequency in situ optical measurements during a storm event: assessing relationships between dissolved organic matter, sediment concentration and hydrologic processes. J. Geophys. Res., 114, G00F09, doi:10.1029/2009JG000989.